A demonstration of the Faraday´s law of induction by means of a magnetized fidget spinner

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Abstract

We propose a simple demonstration to explain to prospective primary teachers the basic ideas behind Faraday´s law of induction and the generation of electricity. In this conceptual activity, a rotating magnetized fidget spinner induces voltage in a copper coil. In an attempt to make this demonstration more motivating and surprising, the voltage was not measured and analyzed with a voltmeter; instead, we used a loudspeaker to listen to and understand the induction of electricity. It is therefore a variation of the classical experiment of the bar magnet sweeping through a solenoid.

Keywords

Electromagnetism, sound, pre service teachers, primary school

Funding Statement: The study was supported by the project 'Ciencia a lo Grande' from the Cabildo Insular de Tenerife, Spain.

Conflict of Interest declaration: The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

1. Introduction

In this work, we present a surprising demonstration where a fidget spinner and a loudspeaker are used to explain Faraday´s law of induction and the generation of electricity to prospective primary teachers. Fidget spinners consist of two or three blades mounted around a ball bearing, that spin with minimal effort. In education, fidget spinners have been used to teach abstract physical concepts such as torque, friction, angular momentum, and moment of inertia [1-3].

Faraday [4] discovered that ´if a terminated wire is moved to cut a magnetic curve, a power is called into action tends to urge an electric current through it'. In other words, Faraday´s law of induction states that an electric potential (voltage), V, is generated by a coil of wire of N turns when a magnetic flux, Φ, enclosed by it changes over time.

$$V = - N\, d\Phi/dt \qquad (1)$$

The idea expressed in equation (1) is difficult to explain to prospective primary school teachers because of their poor scientific and mathematical background (at least in the Spanish case). Many different strategies have been implemented to make it more accessible and less boring, particularly for students who are not pursuing a science-related career [5]. One of the most successful strategies consists of explaining how everyday devices work, that is, loudspeakers [6,7], electric motors, and generators [8,9]. The connection between abstract concepts (electromagnetism) and common devices (fidget spinners, speakers, and smartphones) is the basis of the demonstration implemented in this study.

2. The demonstration

This demonstration is a conceptual explanation of equation (1), where a fidget spinner that is held in one hand moves magnets to change the magnetic flux, Φ, whereas the voltage, V, generated in a coil is 'listened' through a speaker. It is indeed a twist of the classical induction experiment that consists on measuring, with a voltmeter, the voltage induced by sweeping a strong bar magnet through a solenoid [10].

These are the materials needed to prepare the activity (see Figure 1): a fidget spinner, three neodymium magnets (that will be fixed to the ends of the blades of the fidget spinner, recalling we are using a metallic spinner), an amplified speaker with gain (this is important, since the voltage generated is very low), a smartphone running the application phyphox (https://phyphox.org, [11]) to measure properties of the sound emitted by the speaker, a coil of enameled copper wire (in our case with 50 turns) and an audio cable. The two ends of the coil were connected to the ground and the signal of the audio cable.

The demonstration works as follows (see Figure 2): We plug the audio cable into the amplified speaker, set the gain to max, and start recording the sound amplitude with phyphox. We held the fidget spinner with one hand and gave the blades a strong push to make the magnets spin as fast as possible. The spinner was placed parallel to the coil, one centimeter away. The variable magnetic field induces a small voltage in the coil. This voltage is ´translated´ into a sound by the amplified speaker. As a result, the sound of the rotation of the fidget spinner will be heard from the speaker. The students listen to how the spinner slows down and the amplitude of the sound decreases; the variation in the amplitude of the sound as a function of time can also be seen in the graph generated by phyphox (that is projected onto the classroom screen). This is extremely surprising for prospective teachers, particularly if we suddenly stop the spinner and the sound ceases.

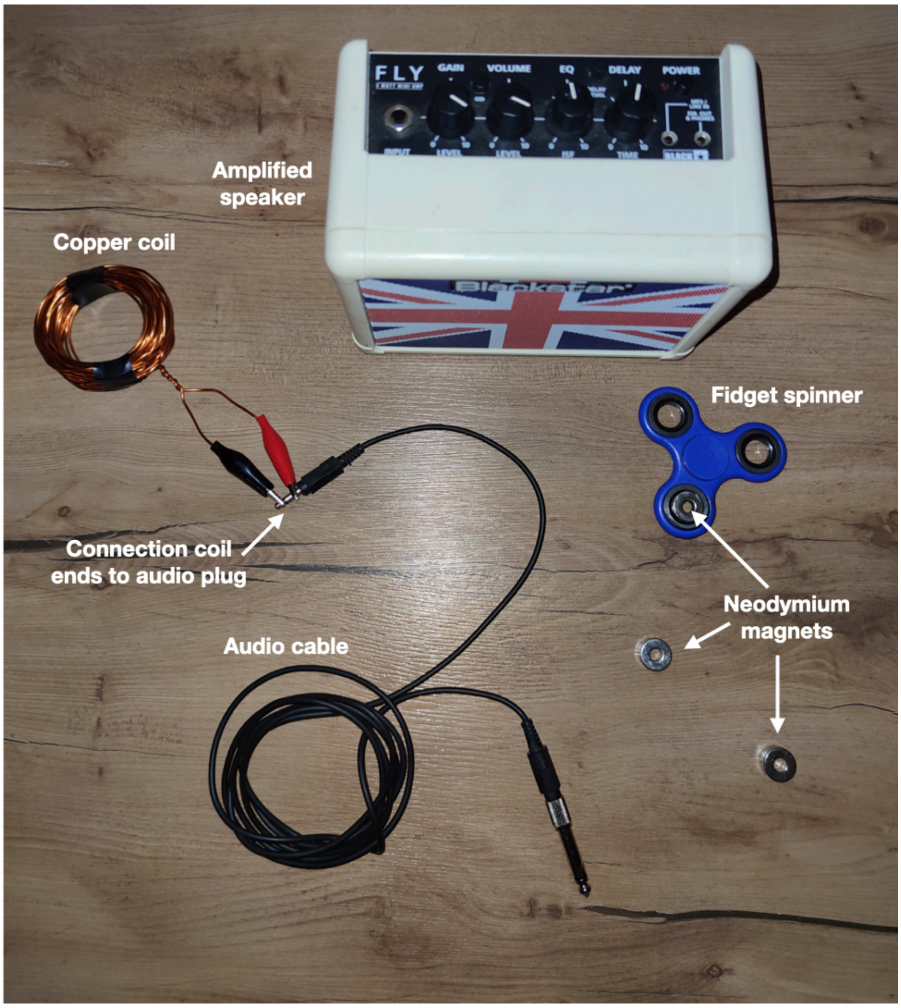

Figure 1. Picture showing all the components of the demonstration, including the setup of the connection between the coil and the audio cable.

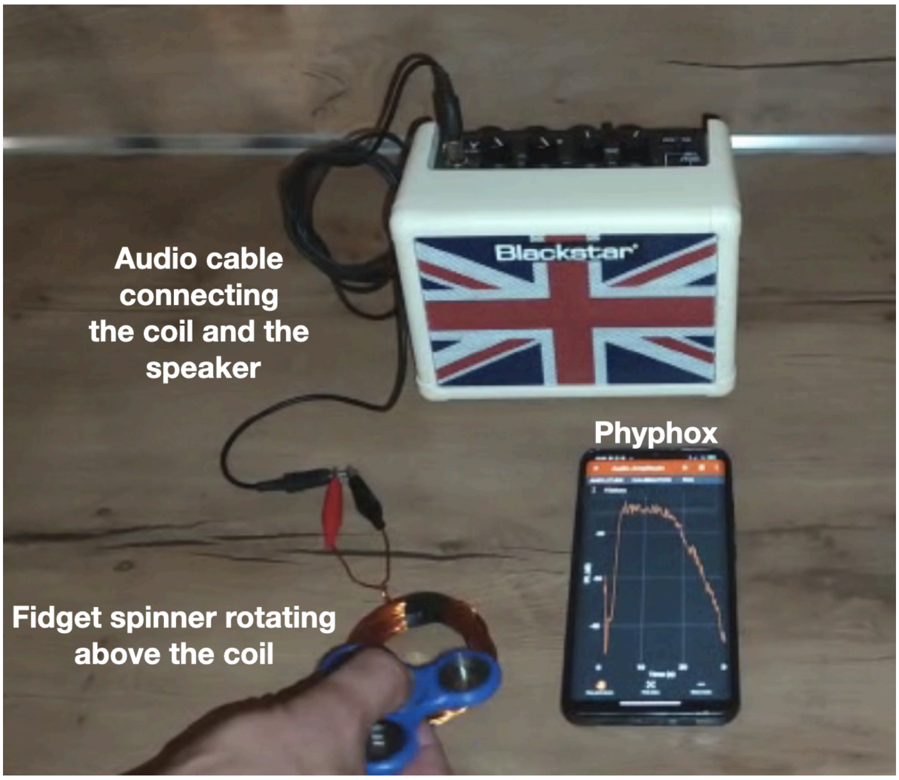

Figure 2. Snapshot of the demonstration, where the rotating spinner, with the magnets at the ends of the blades, is held in one hand above the coil. The gain and volume of the speaker are set to max, whereas the application phyphox is recording and plotting the amplitude of the sound, that is related to the voltage of the coil. Click on the figure to watch a video about the demonstration.

It is easy for prospective teachers to relate the velocity of the spinner to the amplitude of the sound they listen to or see in a graph. The demonstration connects the velocity of the spinner with the change in the magnetic flux, and the sound of the spinner emitted by the speaker with the voltage induced by the coil, as expressed in Equation (1).

We repeated the activity, but removed the magnets from the spinner. In this case, no sound was emitted from the speakers. We asked the students what happened to check their understanding of the relationship between the change in magnetic flux and the induction of a voltage. Finally, we connect the demonstration to the actual generation of electricity, relating the rotation of the fidget spinner with the rotation of the blades of a windmill or turbine in a hydropower or thermal plant.

This conceptual activity was designed for preservice primary school teachers to provide them with the basic ideas behind electromagnetic induction, but also with different tools, resources, and strategies to teach science. This demonstration could be easily adapted to other educational levels (undergraduate introductory physics or high school physics) to quantify how the voltage (sound amplitude) depends on the speed of the spinner, the number N of turns in the coil, and the distance and orientation between the coil and spinner. In this case, we could save and analyze the data (sound amplitude and magnetic field) recorded by the phyphox application. However, this was beyond the scope of this study.

3. Results

This demonstration has been put into practice for three consecutive years as part of a course on science educational resources for prospective primary teachers at the Universidad de La Laguna in Spain. A total of 460 students participated in this activity. The most common reaction is surprise; they claim that it is truly amazing how electricity is generated through contactless interaction between the moving magnets and the coil. They also highlighted the ease of setting up the experiment in terms of materials and time. Most importantly, these types of demonstrations are inspiring for them and their future careers as primary school teachers as they learn different methods of teaching science and engaging with primary students.

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